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Corporate Repair Philosophy and Measuring for Continuous Improvement at Philadelphia Naval Shipyard

No. 4B-1

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ABSTRACT

Initial zone technology implementation at the Philadelphia Naval Shipyard (PNSY) in 1986 set the stage for one of the most significant shifts in culture and repair philosophy ever witnessed at a public naval shipyard. Attempting to fundamentally change the way that the shipyard conducted business forced senior and middle management to completely understand the dynamic and interrelated processes that were utilized to perform depot level work. Through the Philadelphia Quality Process (PQP), this understanding was achieved and changes that were necessary to shift from a Ship Work Breakdown Structure (SWBS) to a Product Work Breakdown Structure (PWBS) began.

As all quality processes will point out, measurement is the key to obtaining the necessary data to make corporate decisions. As the zone technology model was refined from 1987 through 1991, the understanding of "how we do work" continued to improve. Attacking processes that are sluggish, manual and not responsive enough to support the manufacturing process is the direct result of meaningful measurement focusing management attention. The purpose of this paper is to point out that the emphasis of the shipyard is **now** on the total "manufacturing process" rather than just "odds and ends" of planning and production. The utilization of zone technology provided the environment and attitude that supported improvements from within. Shipyard goals remain constant: improve producibility, reduce cost, and maintain quality. Continuous measurement, analysis and action to improve the shipyard's manufacturing process has been the mechanism used to achieve those goals.

ACRONYMS AND DEFINITIONS

AOE: Auxiliary, Oil and Explosives. The Navy letter designation for a combination oiler-ammunition ship.

AVT: Aircraft Carrier, Fixed Wing, Training. The Navy letter designation of a training aircraft carrier.

BB: The Navy letter designation for a battleship.

CAD: Computer Assisted Design. Design drawings and models produced utilizing computers.

CKO: Closed KEOP. A key operation which is completed.

COB: Complex Overhaul. The Navy term for an extended overhaul period where major repairs and alterations are conducted.

CPI: Cost Performance Index. The (CS)' term representing the ratio of expenditures vs. physical progress on completed work and work in progress.

(cEq: Cost/Schedule Control System. Shipyard computerized system to track expenditures and physical progress vs. budget and time allocations for authorized work.

OV: Carrier, Fixed Wing. The Navy letter designation for an attack aircraft carrier.

DD: The Navy letter designation for a destroyer.

DSR: Design Service Request. The formal method where production shops request engineering assistance from the design division.

DSRA: Docking Selected Restricted Availability. The Navy designation for a planned, short-term, drydocking shipyard availability.

EDD: Estimated Delivery Date. Normally used when discussing material delivery requirements.

FF: The Navy letter designation for a frigate.

FON: Fiber Optic Network. A specific type of LAN utilizing fiber optics as the physical link between stations.

BP&A: Hull, Propulsion and Auxiliary. The acronym used to identify work as being part of the hull, propulsion or auxiliary systems on a ship.

IDP: Integrated Design Package. A three dimensional CAD drawing which overlays all systems in a given area to assure that no interferences exist.

JOPC: Job Order Process Card. The document used to specify work to be accomplished on an equipment or system and identify shops and budgets allowed.

KEOP : Key Operation. The lowest level non-trade unique, work instruction.

LAN: Local Area Network. The term used to describe the hardware and software link between computer systems and workstations.

NIIP: Navy Industrial Improvement Program. A program sponsored by the Secretary of the Navy which had the goal of improving processes and products of Navy depot-level activities.

P&E: Planning and Estimating. The shipyard office responsible for job planning, estimating and scheduling.

PF: Performance Factor. The ratio of expenditures vs. allowances (normally on completed EEOPs).

PQP: Philadelphia Quality Process. The Philadelphia Naval Shipyard's version of Total Quality Leadership/Management.

PWBS: Product Work Breakdown Structure. The identification scheme used to identify ship work by products, normally by a geographic area.

RDD: Required Delivery Date. Normally used when discussing material delivery requirements.

SARP : Ship Authorized Repair Package. The contract between the shipyard and the customer concerning the repair and overhaul of a specific ship.

SLEP: Service Life Extension Program. An overhaul program designed to increase the service life of conventionally powered aircraft carriers by 15 years.

SLQ-32: An electronic warfare system installed on most U.S. Navy combatants.

SWBS: Ship Work Breakdown Structure. The identification scheme used to identify ship work by system.

TQL: Total Quality Leadership. The U.S. Navy's management program which strives to assure continuous improvement in all productive processes.

WMT: Waterfront Management Team. A group of production, planning, supply and other department personnel directly supporting the execution of a ship overhaul.

INTRODUCTION

As the management team of a non-nuclear public shipyard operating in an increasingly competitive environment, Philadelphia Naval Shipyard senior managers have understood that a strategic plan, commitment to quality and a corporate repair philosophy were needed in order to ensure the viability of the shipyard. In 1988 the shipyard entered a program; quality education designed to a fundamental attitudes concerning quality at the shipyard. This process, known as the Philadelphia Quality Process (PQP) has been accepted as the method for assuring continuous improvement in shipyard processes. In 1989, shipyard senior managers, with the assistance of the Navy Industrial Improvement Program (NIIP) began a series of discussions which centered on the development of a shipyard five-year strategic plan. The strategic plan provided the focus, utilizing PQP as a vehicle to assure continuous improvement, and the necessary communication required to "make it work" form the foundation of Total Quality Leadership (TQL) (figure 1) -

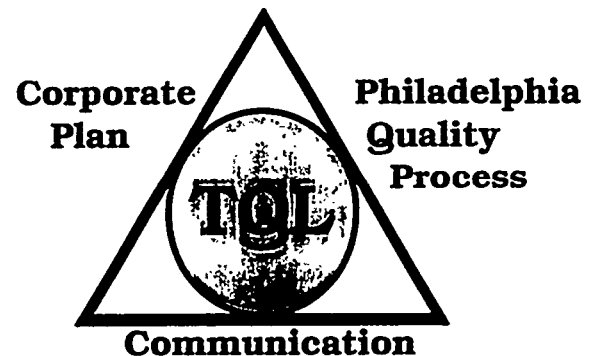


Fig. 1 TOTAL QUALITY LEADERSHIP

As a means of improving its competitive posture, the shipyard has made a fundamental shift from a systems-oriented approach to ship repair and modernization to a product-oriented overhaul management philosophy. This product-oriented overhaul philosophy, also known as zone logic technology has

become the accepted means of planning and executing work at the shipyard and is the foundation of the shipyard's corporate repair philosophy.

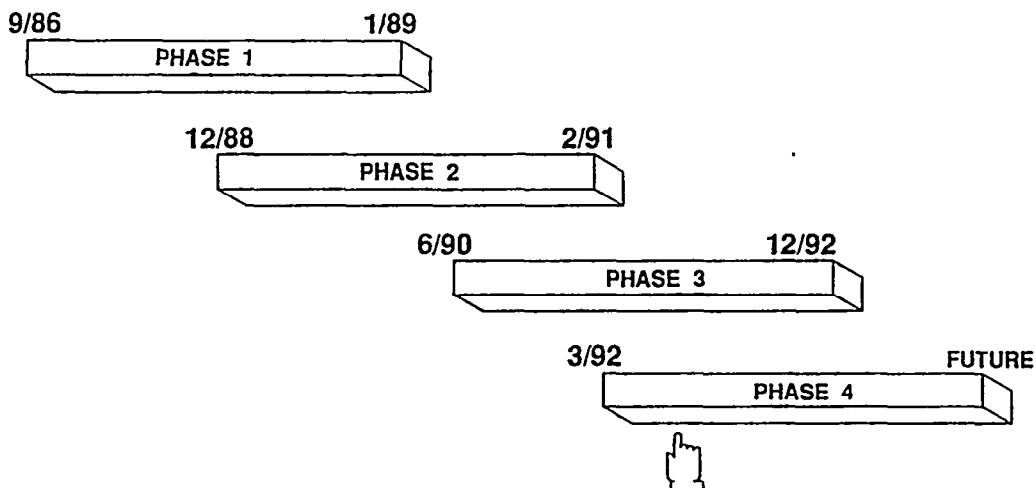
The introduction of zone logic technology at the shipyard actually began in 1986 with the Service Life Extension Program (SLEP) of the USS Kitty Hawk (CV-63). This initial phase of zone logic implementation was conducted on approximately 35% of a 1.7 million man-day, 37 month duration project. The methods and organizational structure used for zone logic on the Kitty Hawk SLEP have been discussed in detail by Baba, et al (1). While evidence of many potential improvements in ship repair practices were apparent, the shipyard experienced considerable difficulty in having zone logic accepted by all shipyard management and workforce. Prior to entering the planning stages for the USS Constellation (CV-64) SLEP in 1988, shipyard management evaluated the pros and cons of zone technology and made the decision to continue using zone technology as the method to planning and executing ship overhauls. Burrill, et al (2) summarize the methodology used on Kitty Hawk SLEP and the process of applying lessons learned to USS Spruance (DD-963) Drydocking Selected Restricted Availability (DSRA) and subsequently, USS Constellation SLEP. Petersen-Overton (3)

discussed numerous changes made in the planning and production organizations prior to USS Constellation SLEP and reported on the initial results from this project as well as the results of zone technology implementation on smaller availabilities.

The SLEP of the USS Constellation is now at 80% completion. This presentation studies the current status of the Constellation SLEP and evaluates the results of changes made in the shipyard's corporate repair philosophy including zone technology implementation, project management and the quality process used to measure and improve on this project. In addition, numerous other changes and improvements in the way of planning and executing a complex ship repair and alteration project have been made at the shipyard. These changes and their effect on productivity on the Constellation SLEP are discussed.

STATUS OF ZONE TECHNOLOGY IMPLEMENTATION

As zone technology implementation extends into its seventh year, the shipyard is entering a new phase in the implementation plan. Petersen-Overton (3) described this as a four-phase plan. Figure 2 illustrates the zone technology implementation plan and its current status.



- PHASE 1:- INITIAL IMPLEMENTATION INCLUDING THE FIRST YEAR OF EXECUTION ON KITTYHAWK
- PHASE 2:- PLANNING PHASE FOR USS CONSTELLATION SLEP, COMPLETION OF USS KITTY HAWK SLEP AND EXECUTION OF USS SPRUANCE AND USS HEWES
- PHASE 3:- EXECUTION OF USS CONSTELLATION SLEP IN CONJUNCTION WITH OTHER COMPLEX OVERHAULS & AVAILABILITIES
- PHASE 4:- PLANNING AND EXECUTION OF USS FORRESTAL AND USS JOHN F. KENNEDY COMPLEX OVERHAULS

Fig. 2 ZONE TECHNOLOGY IMPLEMENTATION PHASES

With the Constellation SLEP nearing completion, and advanced planning started on the USS Forrestal (AVT-59) and USS John F. Kennedy (CV-67) Complex Overhauls (COH), the shipyard is entering Phase IV of the plan. Numerous internal audits of the yard's zone technology planning and production processes and a review of measurements used have been conducted. Phase IV will consist of the application of lessons learned on the Constellation SLEP to the Forrestal and Kennedy COHs. In addition to aircraft carrier overhauls, zone technology continues to be used on other types of ships repaired at the shipyard. Table I lists projects completed or planned using zone logic technology.

- Integrated Planning for Production - an organized, thought out approach to planning and executing the project.
- Work Packages using Zone Technology - specifically the packaging of work into "doable" work packages that are to be executed by trade, by chase, by geographic area.
- Measurement for Continuous Improvement - detailed analysis is conducted on a continuing basis of all in-process work hold-ups and to identify systematic problem areas.

<u>PROJECT</u>	<u>PRODUCTION HOURS</u>	<u>STATUS</u>
US8 KITTY HAWK (CV-63)	550,000	COMPLETE
US8 HEWEB (FF-1078)	18,000	COMPLETE
US8 SPRUANCE (DD-963)	15,000	COMPLETE
US8 CONSTELLATION ((X-64)	806,000	IN PROGRESS
US8 DETROIT (AOE-4)	35,100	COMPLETE
US8 WISCONSIN (BB-64)	30,000	COMPLETE
HS KIXON (D-218)	25,000	COMPLETE
US8 SEATTLE (AOE-3)	36,000	MAY 1992
US8 FORRESTAL (AVT-59)	275,000	SEPT 1992
US8 JOHN F. KENNEDY (CV-67)	700,000	BEPT 1993

Table I SONE TECHNOLOGY PROJECT STATUS

US8 CONSTELLATION STATUS

At the 80% point of completion in the USS Constellation SLEP, the shipyard is experiencing a significant improvement in the cost performance of its production shops when compared with previous SLEPs. Figure 3 shows the completed work (closed KEOP) performance factor (actual cost of work performed divided by budgeted cost of work performed) on all five SLEPs to date. The performance factor is plotted against the percentage of time expired. The gains in efficiency indicated at this point in the overhaul shows an average 11% improvement as compared to the previous four SLEPs at the 80% point.

It is generally accepted that the improvements realized are a combined result of several changes made in the way of doing business. These changes represent the corporate repair philosophy and are described below.

- Project Management Implementation - this enables experienced, shipyard production managers to be removed from the daily administrative burdens of running a group or shop and concentrate on project management.
- Waterfront Management Team - this has enabled a team of planning and production project managers to work in the same location, physically near the worksites. Communication and efficiency in handling changes has been vastly improved as the Project Manager has on his team members of all offices required to support the project.

Increased use of Integrated Design products - Areas of the ship which require extensive renovation or

alteration have individual systems designs integrated in a three dimensional Computer Assisted Design (CAD) format. Interference control and resultant work stoppages are drastically reduced.

- Increased use of Design Aids for Producibility - use of initiatives such as photogrammetry for ship checks and automated thru-ship cable routing instructions have vastly improved the accuracy and control of work packages provided to production shops.

CORPORATE REPAIR PHILOSOPHY

Integrated Planning for Production

It is no secret that emphasis placed on up-front planning will result in a smoother-flowing, better executed availability. But what should this planning consist of? It is not enough for a planning department to issue job orders, issue a schedule, issue drawings, order material and hope that production shops can carry it all out. The shipyard strategized the execution of the Constellation SLEP through an integrated planning and production schedule. This schedule was described by Burrill, et al (2). When the advanced planning for USS Constellation SLEP

began, managers decided that if zone technology were to be successfully applied to Constellation, a total review of the shipyard planning and production process was required. Managers initially drew up a strategy chart which incorporated their individual experience of the ship overhaul planning and execution process. What resulted was somewhat disjointed and lacked direct responsibility for the many sub-processes. The managers, using training received in the quality process, then developed process model worksheets identifying products, requirements and customers in each step of the overhaul process. Through this customer-product relationship, the individual processes were better defined with deliberate relationships identified and clear lines of responsibility spelled out. A "master schedule" was developed which identified the requirements of the shipyard's customer, incorporated experience from four previous SLEPs and took into account long-lead time material delivery schedules. This "master schedule" was used to identify an intermediate product, a production schedule. Through the integrated planning and production schedule, all "suppliers" or support offices were given the requirement to provide their products to support this schedule. These products included material deliveries and receipt inspection, job order and drawing development, test

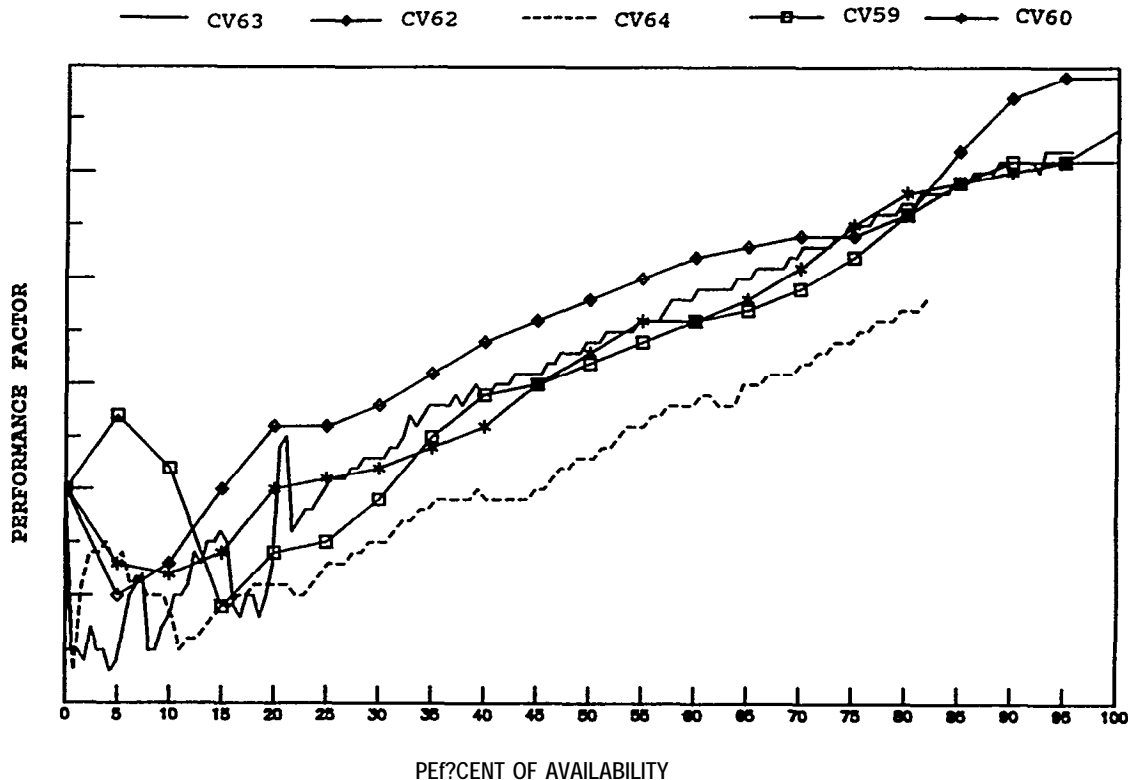


Fig. 3 CLOSED EBOP PERFORMANCE ON Cv-SLEP

SPeCifiCaTiOn writing and work package issuance. The end result is the CV-64 "availability strategy" shown in Figures 4a and 4b. This "availability strategy" has been used as the tool to have all

schedules driven by the production schedule. The sub-processes which support this availability strategy are then measured to assure conformance to the schedule and continuous improvement-

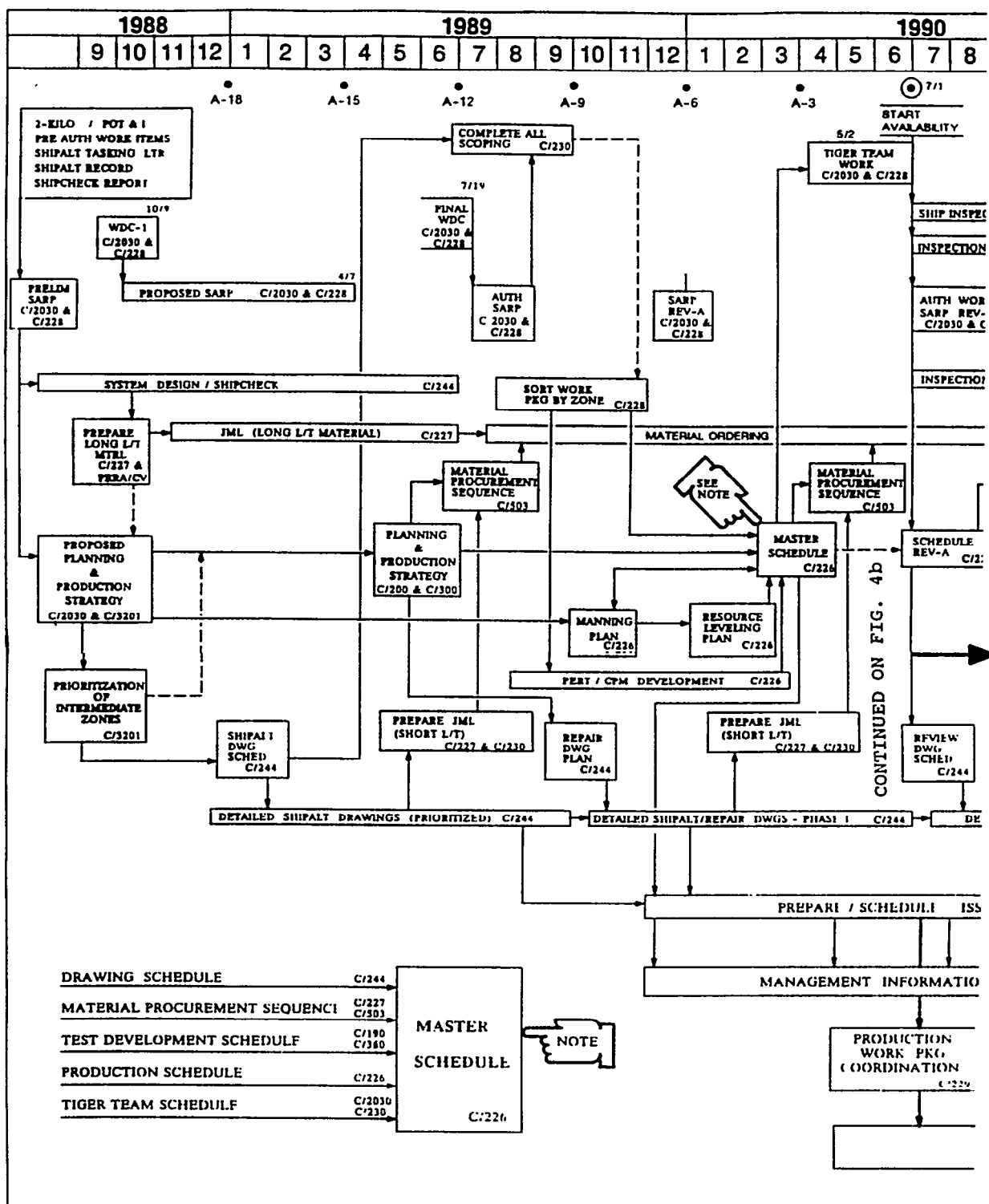


Fig. 4a USS CONSTELLATION AVAILABILITY STRATEGY

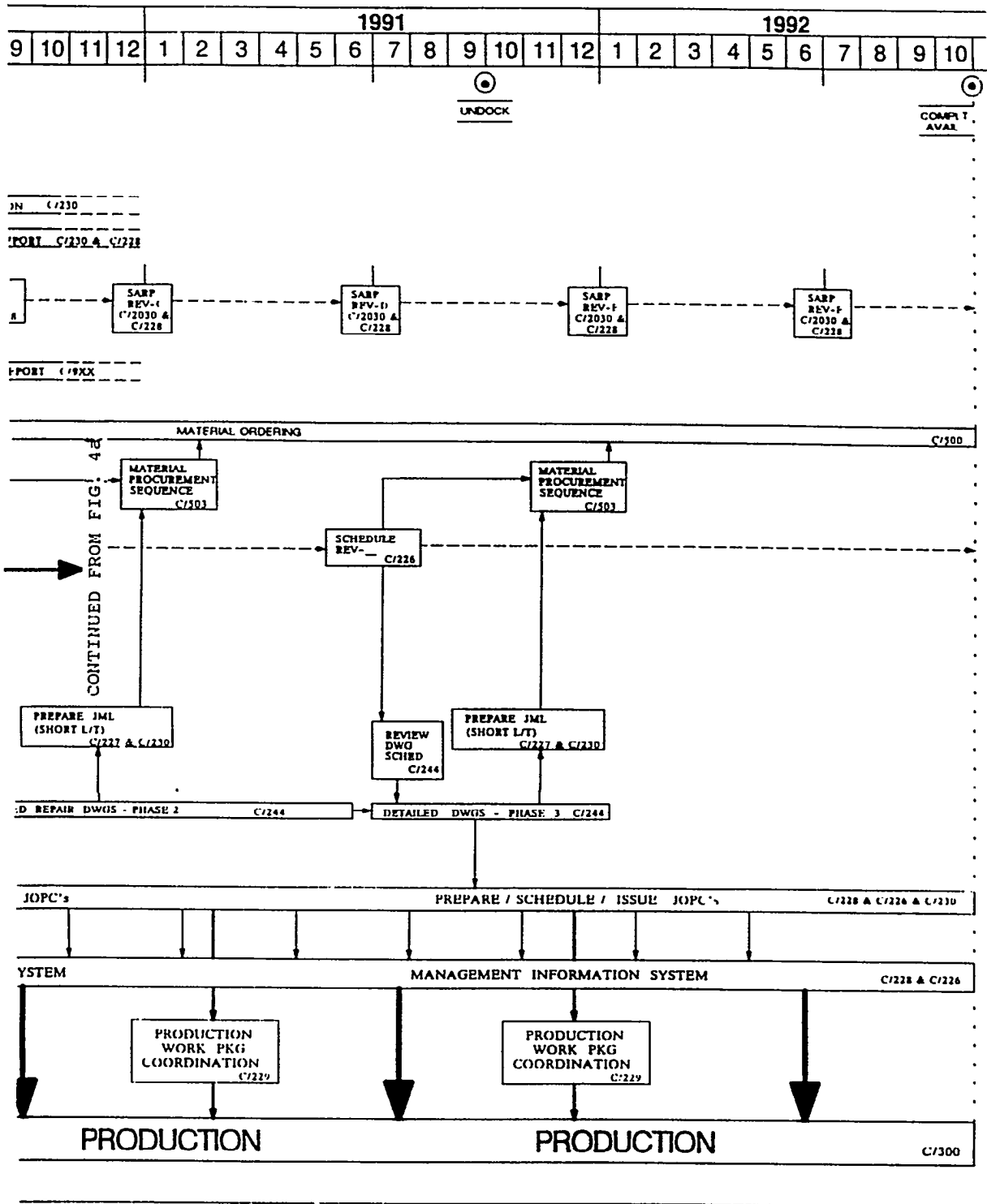


Fig. 4b USS CONSTELLATION AVAILABILITY STRATEGY

Work Packaging Utilizing Zone Logic

In order to simplify and organize the number of products which were being provided to production shops, a work

packaging group has been established. Baba, et al (1) and O'Hare, et al (4) discuss the methodology used by the work packaging group. This group has two main functions listed below.

- 1) Organize the work according to the production schedule and grouping it using zone technology principles, that is:
by phase, by trade, by area.
- 2) Provide to production all of the assets which production shops require to complete a job on schedule.

The difference in philosophy from Vraditional¹¹ means of providing products to the shops to the "zone technology method" is illustrated by Figures 5 and 6.

The work packaging group¹¹ product,¹⁴ the work vackaue, combines all of the information, authorization and material required of a shop to execute work. This includes scanned-in sections of process instructions, scanned-in portions of drawings, material lists including the location of the material, test specifications and, of course the job order process cards (JOPCs) which are the work authorizations and descriptions of work on specific RROPs contained within the work package. The job order process cards and the accompanying information/documentation is grouped and scheduled together to assure that a work package consists of similar work which

is carried out by phase, by trade and are in the same geographic area. In order to assure that the product (work package) is delivered to production shops in sufficient time to execute, the work packaging group schedules individual work packages to be compiled and issued at least 60 days prior to the scheduled start date of that work package. The ability, or inability to deliver the product on schedule is measured as shown in Figure 7.

As a¹¹ customer,⁸⁸ work packaging receives⁸⁸ products* from their⁸¹ suppliers¹¹ which make up the work package. These products may vary with the specific work package but, in general, they are:

- 1 test specifications,
- 1 material lists,
- 1 Job Order Process Cards,
- 1 material inspection certifications,
- 1 drawings or design instructions, and/or
- 1 other sources of information.

The ability of the work packaging "suppliers" to meet their requirements is measured as a number of non-conformances which prohibit timely issue of work to production. Examples of these measures are discussed in the following sections.

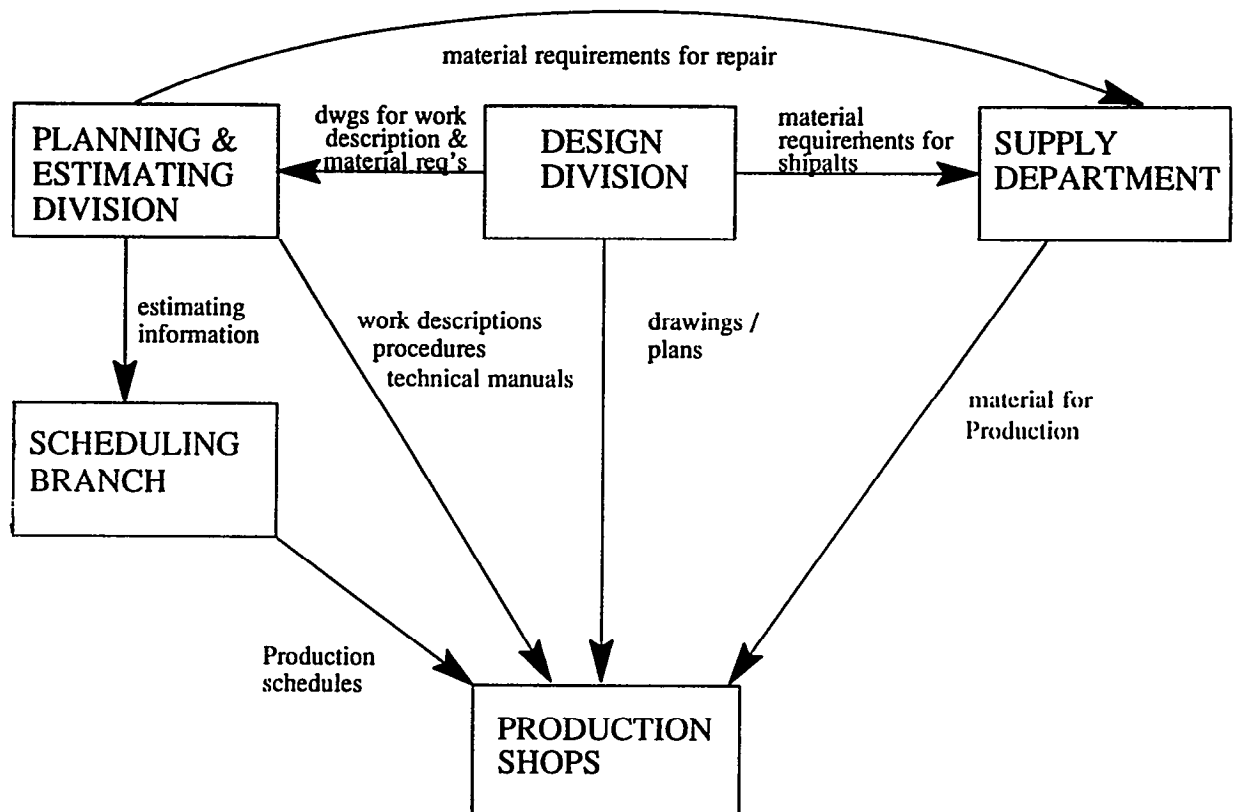


Fig. 5 "TRADITIONAL" PLANNING PROCESS

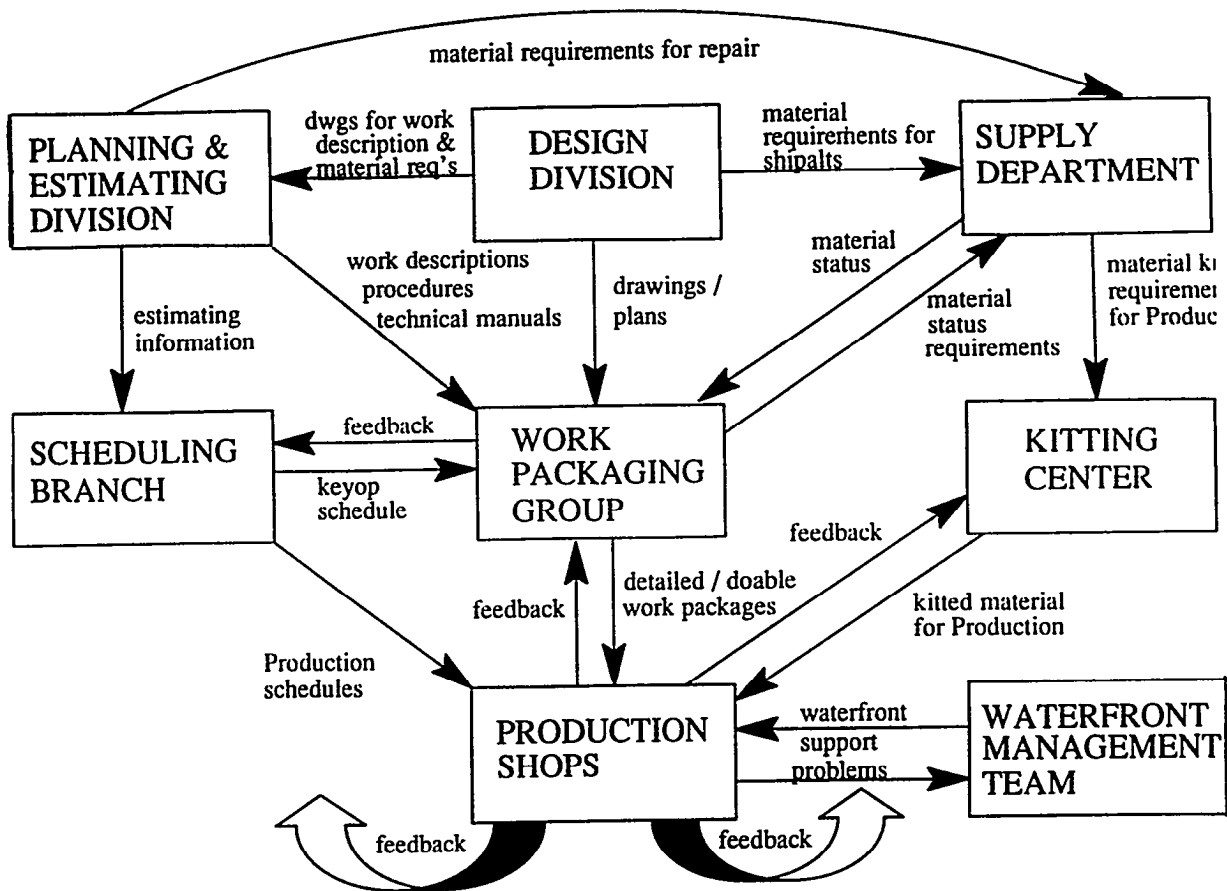


Fig. 6 ZONE TECHNOLOGY PLANNING PROCESS

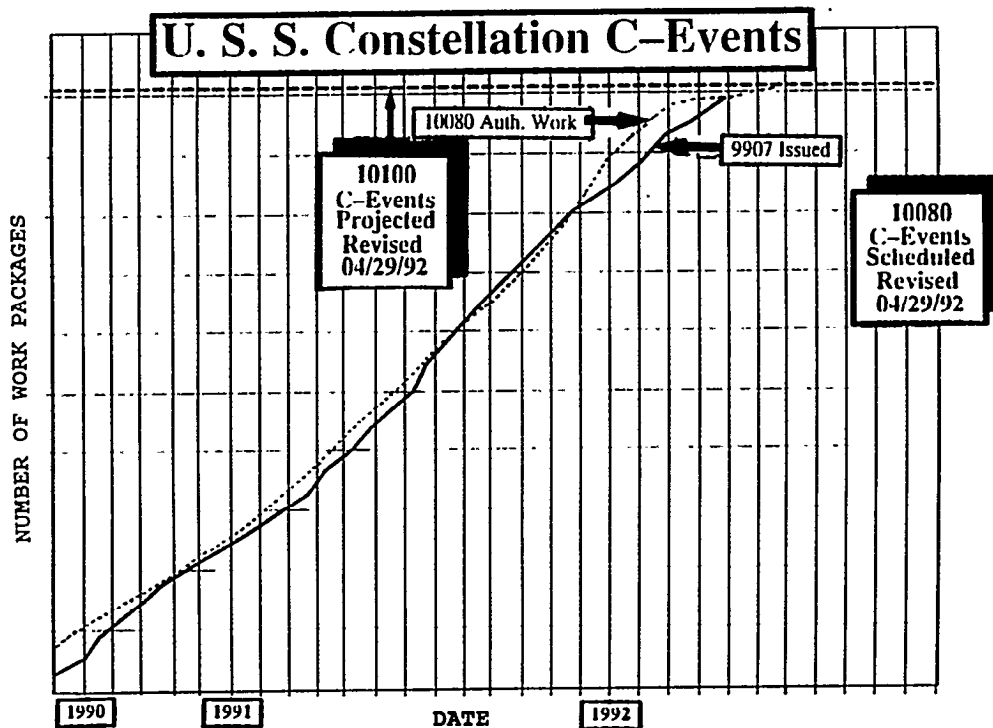


Fig. 7 WORK PACKAGE SCHEDULE ADHERENCE

Test specifications. The issuance of test specifications is required at least 150 days prior to the scheduled start of that test. This lead time allows planning adequate time to identify any additional repairs or materials required to allow the test specification to be met satisfactorily the first time. Figure 8 shows a number of non-conformances to this 150 day requirement on the part of the Hull, Propulsion and Auxiliary (HP&A) test writing branch. Here, non-conformances are measured against calendar time and indicate an improving trend.

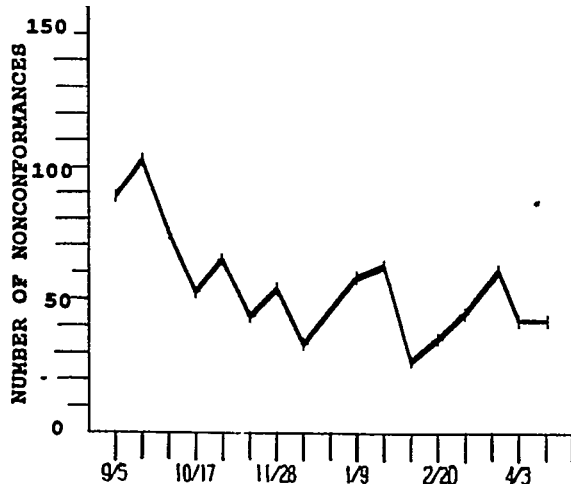


Fig. 8 TEST SPECIFICATIONS
ISSUED MEASUREMENT

Material Dues. Through adherence to the integrated planning and production schedule and zone technology principles, all material ordered is assigned a specific job order and key operation (KEOP). This makes it possible to assign latest required delivery dates (RDDs) of all material ordered based on the date the work is scheduled to start. This allows the shipyard material ordering branch and supply department to know precisely when material is required. The RDD will not change unless the schedule should change. Since material orderers, purchasers and expeditors know in advance when production requires the material, the "crisis management" approach to expediting material through the various steps of the procurement process has been significantly reduced. In order to identify potential material problems early on, a 120 day window has been selected to measure "material dues". Figure 9 shows a sample of this material dues measurement. Here, the solid bar indicates the number of material line items due with RDDs past due or RDDs

within 120 days. The asterisks and connecting line indicates the number of material dues within this window which have a "bad" estimated delivery date (EDD), that is the EDD is after the RDD. The cross-hatched bar indicates the number of material dues which are assigned to KEOPs which are closed (completed) or canceled. Material dues on closed or canceled work are reviewed to determine if these orders should then be canceled.

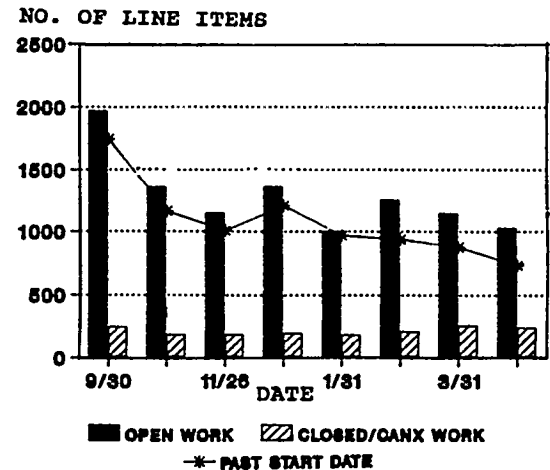


Fig. 9 MATERIAL DUES MEASUREMENT

Material Inspection. Among the lessons learned from the Kitty Hawk SLEP is that receipt inspection for quality assurance was frequently a bottleneck in getting material to production. Since RDDs were not tied to each material line item ordered, it was impossible for the receipt inspection branch to know in advance what material was needed immediately on the waterfront and what should have gone into temporary storage pending need. The priority of receipt inspections are now tied to KEOP and work package start dates. Receipt inspection is measured by viewing a 75 day window prior to the work package start date. All material requiring inspection for work packages past its start date or scheduled to start within the next 75 days are measured. Figure 10 shows a sample graph of receipt inspection measures. Here, the inspections pending are categorized as:

- 1) material not yet received in the shipyard,
- 2) material received but not on-site for inspection,
- 3) material in inspection backlog, or
- 4) material lost.

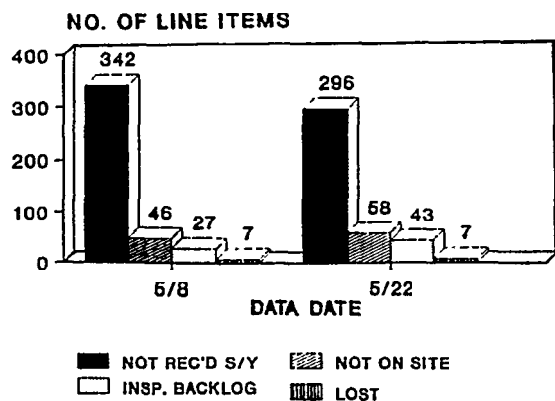


Fig. 10 MATERIAL INSPECTION MEASUREMENT

Work Package Hold-Ups. As previously discussed, the work packaging branch has a requirement of issuing work to production at least 90 days prior to the start date of that work package. In order to measure the non-conformances which are preventing issuance of complete work packages, the work packaging branch measures non-conformances and categorizes according to reason for hold-ups. These hold-ups are presented to responsible codes on a weekly basis for action, and are discussed by senior management on a bi-weekly basis. The categories of hold-ups and examples of causes are shown below:

- 1) Production Shops - due to late submission of an as-found condition report;
- 2) Type Desk - due to late release of reservation or funding by the customer for identified work;
- 3) Planning/Estimating - due to late issuance of an authorized job order;
- 4) Design - due to late issuance of design instructions or plan revisions;
- 5) Combat Systems Office- due to late issuance of test specifications; and
- 6) Hull, Propulsion & Auxiliary (H,P&A) - due to late issuance of test specifications.

Figure 11 gives an example of work package hold-up measures.

Measurement for Continuous Improvement

Thus far, measurements of the planning process have been discussed. Numerous other issues can cause work stoppages. Through the principle of measurement for continuous improvement, roadblocks and bottlenecks which delay the manufacturing process once production shops start work are identified, analyzed and corrected.

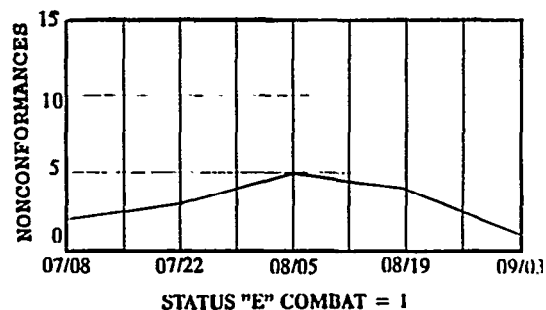


Fig. 11 MEASUREMENT FOR WORK PACKAGING HOLDUPS (COMBAT SYSTEMS DIVISION)

Some of the measures used in this analysis are:

- 1) reschedule action analysis;
- 2) shop report analysis; and
- 3) Design Service Request (DSR) analysis.

Reschedule Action Analysis. When work packages cannot be completed on schedule, a rescheduling may be justified. Shipyard management requires that each reschedule action be clearly categorized by cause for the reschedule. Causes are then studied to identify and correct systematic problems. Typical categories for rescheduling are:

- 1) production shops - worksite not available due to pre-requisite work not completed, sufficient manning or equipment not available;
- 2) planning - work package not issued;
- 3) supply - material not in yard; or
- 4) sequence - work improperly scheduled.

A sample measurement of reschedule actions is shown in Figure 12.

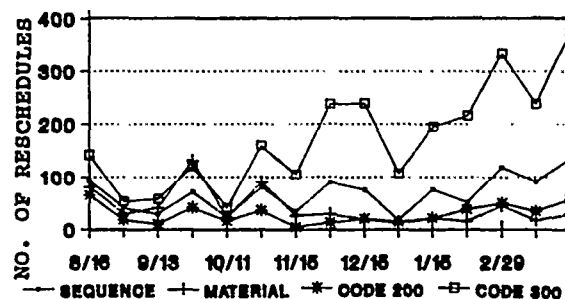


Fig. 12 RESCHEDULE CAUSE MEASUREMENT

Shop Report Measurement. Shop reports are used to identify as-found conditions or to identify inconsistencies

in planning documentation. Total number of shop reports outstanding and the shipyard office responsible for answering are reported weekly. Managers are advised of outstanding actions they have and corrective action required. Figure 13 shows by office, where the outstanding shop reports are for action. Typical categories are:

- Code 214 (Type Desk): requires authorization of work:
- Code 300 (Production Shops): solicited shop report overdue for submission:
- Code 503 (Supply): missing or incorrect material problem:
- Code 225 (Planning and Estimating): requires estimate or routing of work: and
- code 244 (Design): requires engineering analysis.

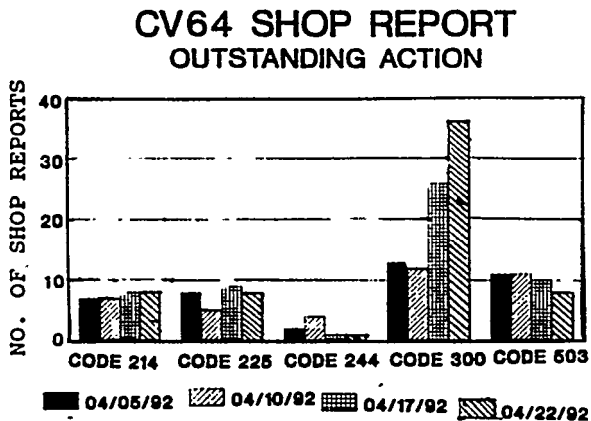


Fig. 13 SHOP REPORT MEASUREMENT

Design service Request Analysis. As many Design Service Requests indicate a work stoppage in a given job, design division is measured on its ability to satisfactorily answer DSRs in a timely fashion. Any DSR which is determined to be "urgent" or a work stoppage requires a 24-hour turnaround.

Project Management

Petersen-Cverton, (3) discussed the projectmanagementorganizationdeveloped for USS Constellation SLEP. Project management at the shipyard has since evolved to the point that the production department has divided into two separate departments. These are the production resources department (Code 300) and the operations department (Code 3300). This reorganization is a natural one given the emphasis and responsibility placed on project managers. The Operations Officer now reports directly to the Shipyard Commander on matters relating to the execution of projects at the shipyard. Each project is assigned a project superintendent, a senior group superintendent level or shop head level civilian manager. Assistant project superintendents each have several zones assigned as their areas of responsibility. Due to the size of the SLEP work package, zone managers are assigned to manage individual zones and report to an assistant project superintendent. Military or civilian ship superintendents are also assigned to each project. The role of the ship superintendent is essentially unchanged from that described by Petersen-Overton as the individual responsible for interface of shipyard work to ship's force work. Figure 14 illustrates the project management organization.

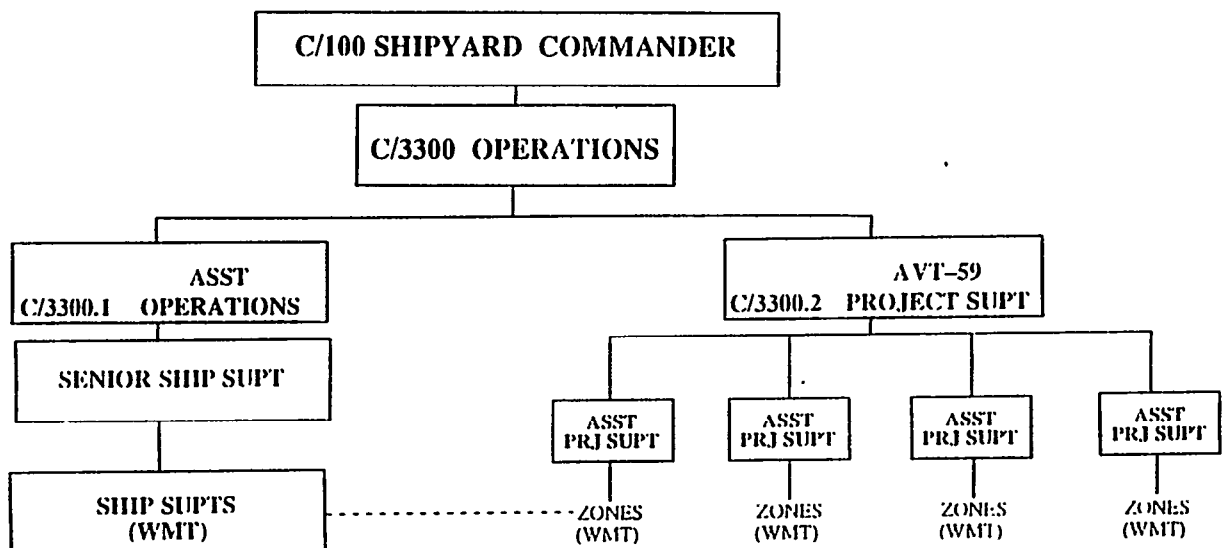


Fig. 14 TYPICAL PROJECT MANAGEMENT ORGANIZATION (AVT-59 COH)

The former production office (Code 300), now the production resources office, also reports directly to the shipyard Commander and is responsible for providing manpower and equipment to the project superintendents for their use. The production resources organization is shown in Figure 15.

It has been recognized that the project management approach to ship overhauls is much more efficient than the previous approach because it allows the senior civilian and military managers to focus on the project at hand. A senior civilian project superintendent will no longer have to be pre-occupied with the myriad of administrative duties which are time consuming and prevent him/her from spending the time needed the project execution. The project superintendents responsibilities are considerable: execution of the project within cost and schedule constraints. There-organization is proving to be the tool he/she needs to succeed. The project management organization discussed above is generic and is tailored for any sized project.

Waterfront Management Team

The philosophy of manning and outfitting complete Waterfront Management Tetm (WMT) to assist the project superintendent in his duties is unique. The WHT is staffed by members of all shipyard offices and departments which are required to keep the project flowing smoothly. While staffing a WRT may be more expensive than the "traditional" work out of the home office

approach, the benefits in improved communication are enormous. It is nearly impossible to measure the efficiency gains made by staffing WRTs but it is accurate to say that, after going through 80% of a SLEP and numerous shorter availabilities with the WMT concept, no manager or office at the shipyard would be willing to operate without them. Each WHT works out of a common trailer or office situated as close as possible to the worksite. These offices are fully outfitted with the required ADP equipment, Local Area Network (LAN) fiber-optic connections, FAX machines, etc. to operate as autonomously as possible. The intangible benefit of the WMT has proven to be the improved communications made possible by the closerworking relationship. WMTmembers, due to their close proximity to the worksite, are also able to spend much more time at the worksite, anticipating and solving problems as they arise. Response time to problems has been greatly reduced as most of shop questions can be answered on the spot rather than waiting for phone calls, calling meetings, etc. Petersen-Overton, (3) has explained in detail, the duties and responsibilities of the individual WMT members. Increased use of computer-aided management tools has proven to be a time-saver for WNTmembers. Currently, the LAN allows on-line cost/schedule and material information, on-line daily status reporting and automation of routine reports. These all serve to allow the project superintendents and WMT members to spend more time "on the deckplates" solving and anticipating problems.

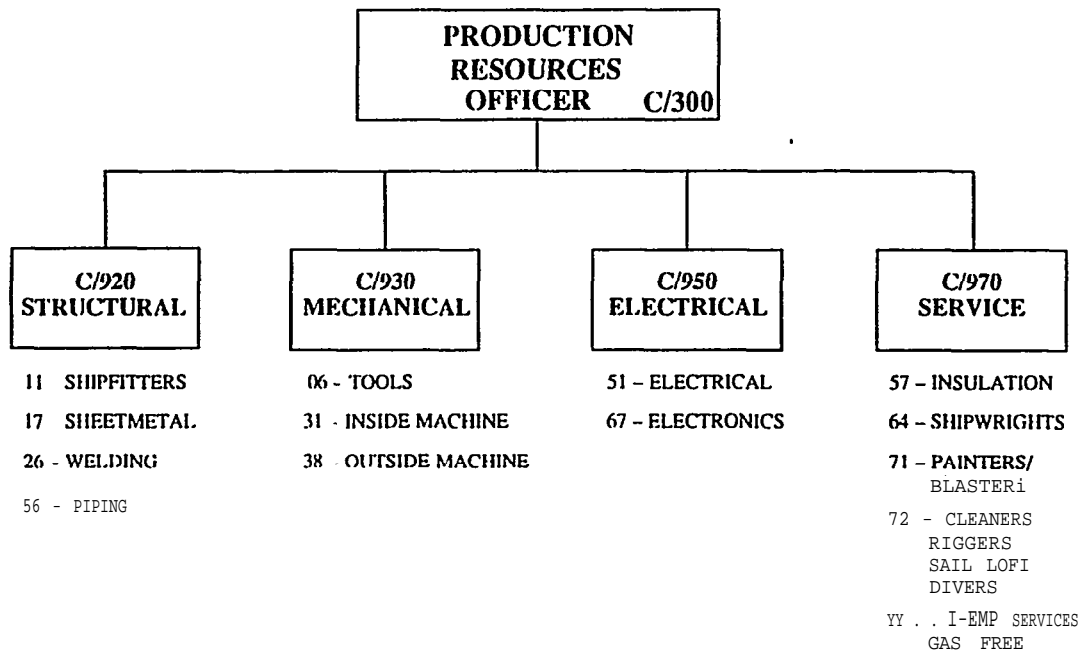


Fig. 15 PRODUCTION RESOURCES ORGANIZATION

Increased use of Integrated Design Packages

Arguto, et al, (5) discuss the use of Computer-Aided Design (CAD) tools to provide Integrated Design Packages (IDP). These products have served to noticeably decrease the amount of interferences and resultant rework in those areas of the ship which are undergoing large scale renovation or re-design. As seen in Table II, there has been a marked increase in the use of IDP from CV-63 SLRP to CV-64 SLEP.

INTEGRATED DESIGN

US8 KITTY HAWK (CV-63)
Pump Room #5
A/C Machinery Rm #3 & 4

US8 CONSTELLATION (07-64)
Pump Room #5
A/C Machinery Rm #1
A/C Machinery Rm #3 & 4
Weapons Magazine
CAT Accum Rm #1
CAT Accum Rm #2
CAT Accum Rm #3 & 4
TAS MK 23 Equip Rm
TAS Clg Equip Rm
Air Terminal Office
Radar Rm #5 (SPN-46)
Radar Rm #9 (SPN-46)
A/G Machinery Rm #1 C 2
A/G Machinery Rm #3
A/G Machinery Rm #4
AN/SPS-48E Clg Equip Rm
Radar Rm #6
Fan Rm
Radar Rm #8
RRE Machinery Rm #1
RRE Machinery Rm #2
RRE Machinery Rm #3 & 4
EW Equip Rm #1
EW Equip Rm #2
NTDS/ASWM CIC
NTDS/ASWM Computer Rm
NTDS/ASWM Aux Rdr Rm

Table II. INTEGRATED DESIGN ON
Cv-63 vs. CV-64

Increased use of Design Aids for Producibility

Photogrammetry. CL'-64 SL?ZP has represented an increase in use of photogrammetry for shipchecks and fabrication information. Sparacino, et al (6) discuss in detail some of the photogrammetry applications and methods used on CV-63 and CV-64 SLEP. Table III shows total usage on CV-64 SLEP compared to CV-63 SLEP. The use of photogrammetry has increased the number of first time fits and significantly reduced the amount of field fitting and welding required on structural modifications.

PHOTOGRAMMETRY

USS KITTY HAWK (CV-63)
Bow Section Repair
Arresting Gear Bolt Holes
Terrier Missile Sponson
Jet Blast Deflector #2

USS CONSTELLATION (CV-64)
Arresting Gear Bolt Holes
Pump Room #5 Shipcheck
SLQ-32 Deckhouse
Jet Blast Deflector #4
Wet Accumulator Fnd #3 h4
Wet Accumulator Fnd #1
Wet Accumulator Fnd #2
Flight Deck Extension
A/C Plant #4 & 5 Shipcheck

Table III. PHOTOGRAMMETRY USAGE
on C'J-63 vs. Cv-64

Automated cable Routing Instructions. USS Constellation SLEP was the first shipyard project to use automated cable routing. Approximately 260,000 m. (850,000 ft.) of new cable is being installed on Cv-64 using nearly 9000 local and thru-ships cable runs. Previous methods provided production quality with termination points of cabling. The shops determined routing of the cables, resultant interference control, etc. This method did not conform to zone technology and resulted in excessive cost. By identifying specific compartments which cables are routed through, planning is able to provide for production not only more accurate cable length information but, more importantly, details where and what size penetrations are to be installed and optimize cable hanger requirements. By establishing a separate job order to cover through-ship cable installations and cable collar installations, logic is applied to through-ship cable and rework is significantly reduced.

RBBULTB

Design Cost Improvements

Certainly, use of IDP, photogrammetry and automated cable routing represents increased up-front costs, but this investment is more than paid off in improved efficiencies. As an example, Figure 16 shows the level of activity of DSR submission on CV-63 SLEP and CV-64 SLEP. Since the CV-63 workpackage was larger than the CV-64 workpackage (1.7 million vs. 1.375 million mandays), the CV-64 numbers have been normalized. Recognize that every DSR submitted represents a problem, or perceived problem identified by production shops which may cause work to stop, and always requires design division investigation and answer. As Figure 16 indicates, approximately 2600 (normalized) DSRs fewer have been submitted at the 80% point of CV-64 SLEP when compared to CV-63 SLEP. Using the conservative figure of four mandays, as discussed by Burrill, et al, (2) to investigate and answer each DSR, this represents a 10,400 manday savings by design division alone! This 10,400 manday figure does not include all of the "rippling effects" of a DSR submittal such as work stoppage, Planning and Estimating (P&E) time to issue new work and material orders if required. This improvement cannot be totally attributed

to increased use of IDP, photogrammetry and automated cable routing but these changes represent a significant portion of overall project efficiency gains.

Production Cost Performance

As discussed earlier, Figure 3 shows cost performance information on all five CV SLEPS. In Figure 3, closed KEOP performance factor (CKO PF) is plotted against time expired. As previously discussed, the CKO PF is a measure of actual charges divided by budgeted charges on all KEOPs which are completed. At the 80% point a significant 11% improvement is indicated by CV-64 SLEP when compared to (X-60, CV-59, CV-62 and CV-63. The CKO PF chart shown in Figure 3 represents production costs only, non-production costs such as design division are not shown.

Production schedule Performance

Figure 17 shows the percent of planned work accounted for in completed KEOPs plotted against time expired. Here, CV-64 data is compared with like data for CV-62 and (X-63. The percentage of work in CKO at 80% is slightly less for CV-64 when compared to CV-63 at its 80% point in 1989 (approximately 67% vs. 70%) and equal to CV-62 at its 80% time expired point in 1987. A portion of the lag which developed at the 55% point was due to an

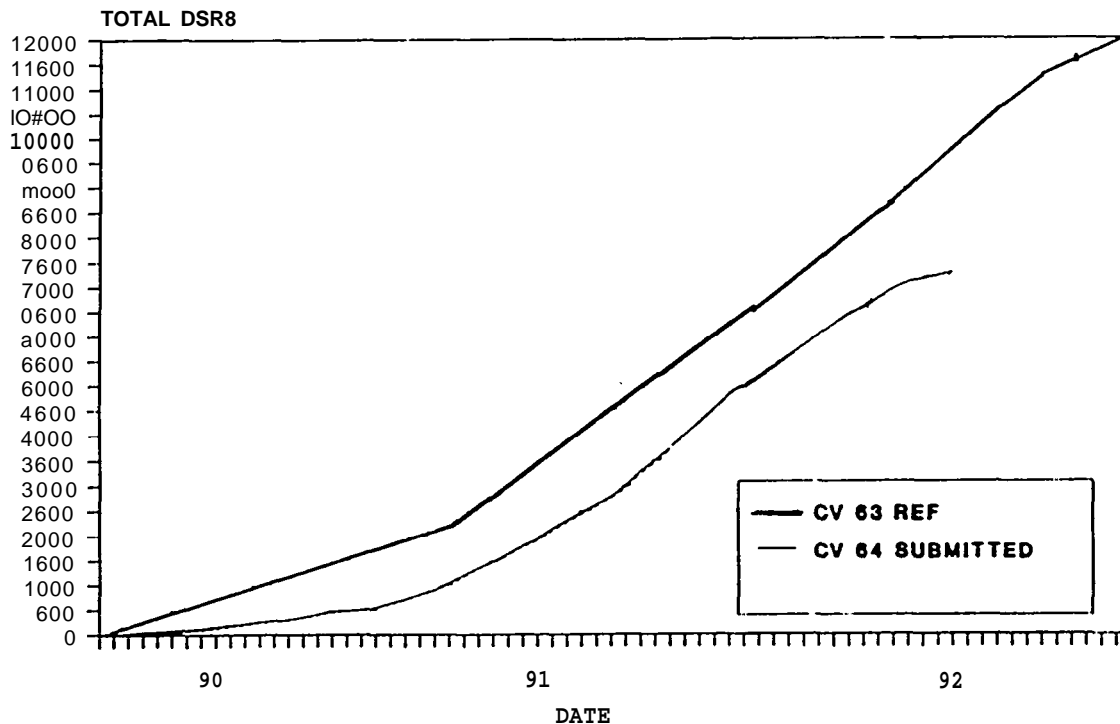


Fig. 16 DSR COMPARISON CV-64 vs. CV-63 (NORMALIZED)

increase in funding and subsequent increase in authorized work by 100,000 mandays. This increase represents a nearly 10% increase in the scheduled work for the CV-64 SLRP. It is not yet known what effect an increase of this magnitude will have on the final performance factor of the CV-64 SLRP. Generally, work picked up late in the scheduled availability is considered high risk and ttcoststl 10-20% more to execute. This may partially offset gains in efficiency which have been made.

Rework

Rework is measured by totalling mandays charged to established rework job orders. Figure 18 shows non-normalized curves for rework accomplishment on USS Independence (CV-62) SLEP, USS Kitty Hawk SLRP and USS Constellation SLEP to date. At the 80% point, the USS Constellation rework performance is encouraging and indicates additional payoffs as a result of zone logic and the corporate repair philosophy.

CONCLUSIONS

Utilizing a carefully developed strategic plan, an established quality process, and zone logic technology as a corporate repair philosophy, the shipyard has exhibited significant gains in the cost of doing business. Zone technology has become the accepted way of planning and performing work and, together with numerous improvements in the planning and production process is beginning to pay dividends. There are always improvements to be made, however, and evaluation and change to the manufacturing process must be continuous. As planning is currently underway for the USS Forrestal and USS John F. Kennedy COHs, "lessons learned" are being applied which will continue to streamline the manufacturing process and complete the shift to logical availability strategies, product-oriented work packaging and successful project execution.

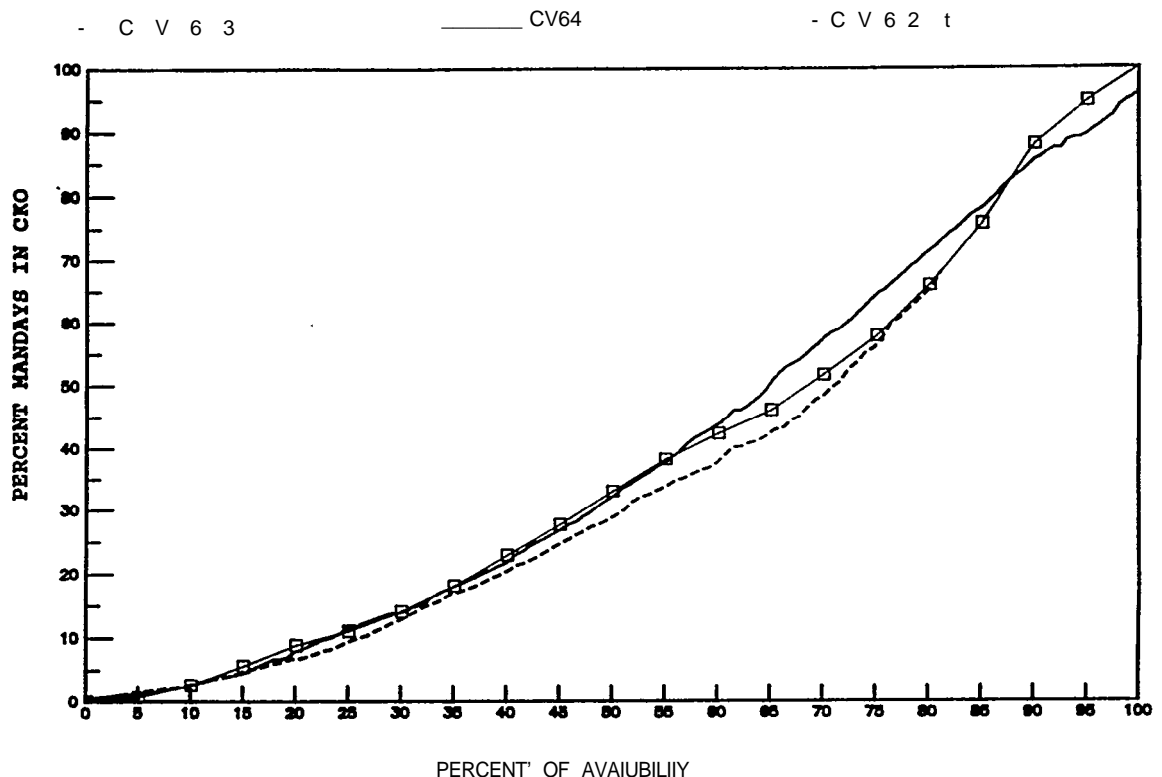


Fig. 17 CV-SLEP PERCENT OF WORK IN CLOSED REOPS

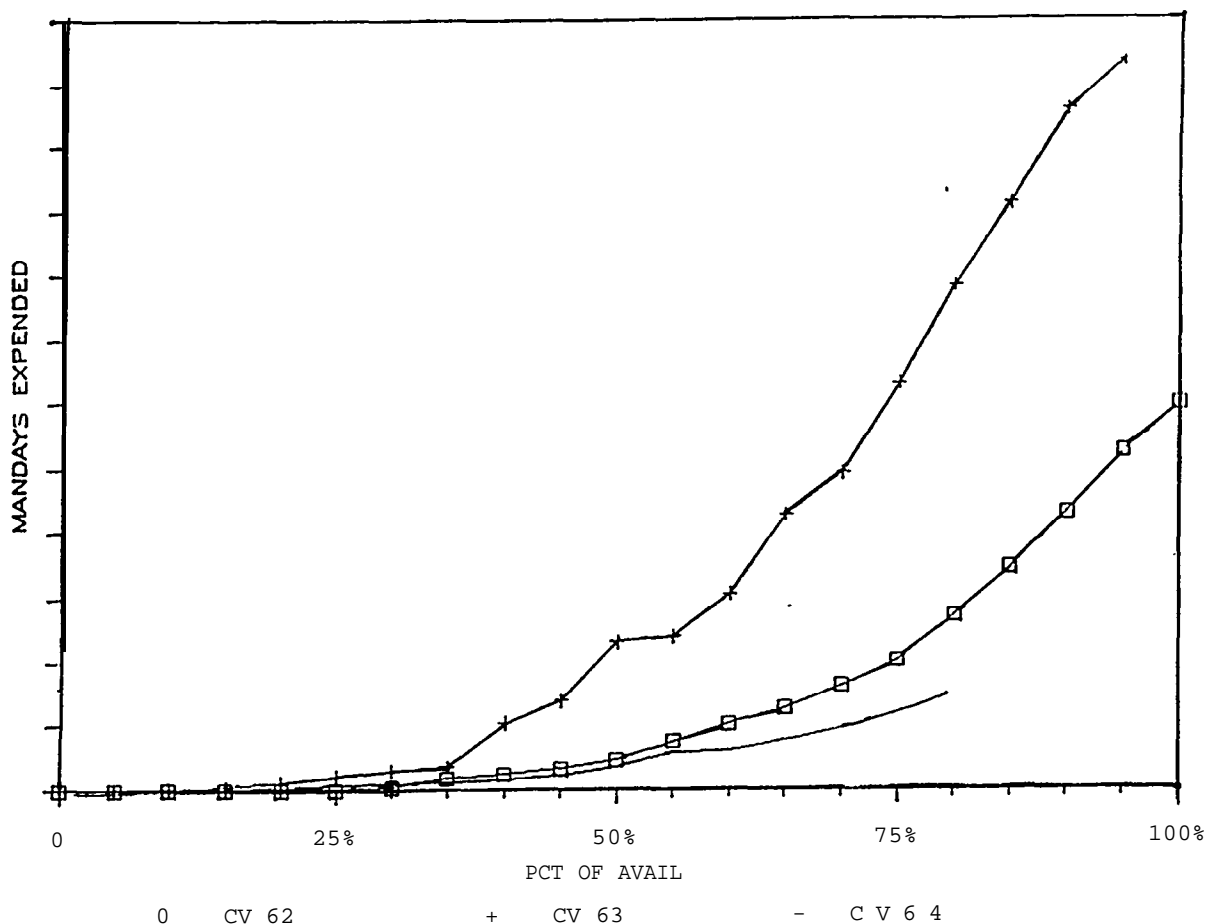


Fig. 18 MANDAYS EXPENDED ON REWOPR, CV-64 vs. CV-62 and CV-63

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